Transition from ideal to viscous Mach cones in a partonic transport model

I. Bouras[1], *A. El*[1], *O. Fochler*[1], *H. Niemi*[2], *Z. Xu*[3], *and C. Greiner*[1]
[1]Goethe-Universität Frankfurt, Germany; [2]University of Jyväskylä, Finland; [3]Tsinghua University, Beijing, China

In relativistic heavy-ion collisions (HIC) at RHIC and LHC a new state of matter, the Quark-Gluon Plasma (QGP), is supposed to be created. In such collisions highly energetic partons propagate through the hot and dense medium and rapidly lose their energy and momentum as the energy is deposited in the medium. Measurements of two- and three-particle correlations in heavy-ion collisions show a complete suppression of the away-side jet, whereas for lower p_T, a double peak structure is observed in the two-particle correlation function. In the last couple of years a promising origin of these structures was assumed to be the interaction of fast and high-energetic partons with the soft matter, which generates collective motion of the medium in form of Mach cones [1].

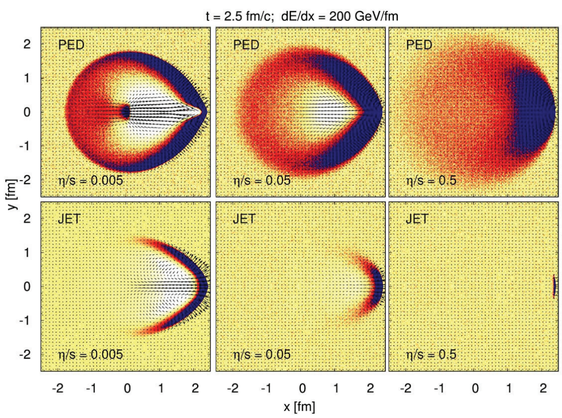

Figure 1: (Color online) Transition from ideal to viscous Mach cones for different shear viscosity over entropy density ratios.

For this purpose we investigate the propagation and formation of Mach cones [2] in the partonic transport model BAMPS (Boltzmann Approach of MultiParton Scatterings) [3] in the limit of vanishing mass and very small shear viscosity over entropy density ratio η/s of the matter. The Mach Cones studied here are induced by two different sources. The first of them we refer to as the pure energy deposition scenario (PED). This is simulated by a moving source depositing momentum end energy isotropically according to the thermal distribution $f(x,p) = \exp{(-E/T)}$. The second source we refer to as JET. This is simulated by a highly massless particle (jet) which has only momentum in x-direction, i.e. $p_{\rm x} = E_{\rm jet}$. After each time step the energy of the jet particle is reset to its initial value.

In Fig. 1 we show the numerical results with $\eta/s = 0.005$, 0.05 and 0.5 from left to right, respectively. We show a snapshot at $t = 2.5\,\mathrm{fm/c}$. The energy deposition rate is fixed to $dE/dx = 200$ GeV/fm. In both scenarios, PED and JET, for $\eta/s = 0.005$ (left panel), a conical structure is observed, but with obvious differences. The PED case with the isotropic energy deposition induces a spherical shock into back region; this structure is missing in the JET scenario because of the high forward peaked momentum deposition. Another difference is that in the JET scenario a clearly visible head shock appears. This in turn is missing in the PED scenario. Furthermore a (anti)-diffusion wake is induced by the JET (PED) scenario. However, with increasing viscosity over entropy density ratio the conical structure smears out. This is shown in the middle and left panel for 0.05 and 0.5, respectively.

However, the more interesting part is the issue, whether a double peak structure is created by the high energetic jets. In Fig. 2 we show the two-particle correlations extracted from BAMPS calculations of the Mach cones shown in Fig. 1. For the JET scenario (a) and sufficiently small $\eta/s = 0.005$ we observe only a peak in direction of the jet. The typical double peak structure, which has been proposed as a possible signature of the Mach cone in HIC, can only be observed for the PED scenario (b) and small η/s. However, the PED scenario has no correspondence in heavy-ion physics. For the JET scenario, which is a simplified model of jets depositing energy and momentum, a double peak structure never appears. This is due to the strong formation of a head shock and diffusion wake.

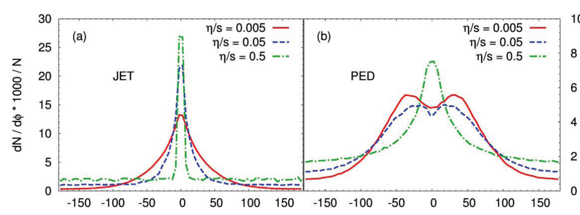

Figure 2: (Color online) Two-particle correlations $dN/(Nd\phi)$ for different viscosities extracted from calculations shown in Fig. 1. The results are shown in the for the JET (a) and PED (b) scenario.

References

[1] Horst Stoecker. *Nucl. Phys.*, A750:121–147, 2005.

[2] I. Bouras, A. El, O. Fochler, H. Niemi, Z. Xu, et al. *Phys.Lett.*, B710:641–646, 2012.

[3] Zhe Xu and Carsten Greiner. *Phys. Rev.*, C71:064901, 2005.